INTERNATIONAL STANDARD

ISO
4869-2

Second edition
2018-10

Acoustics — Hearing protectors —

Part 2:
Estimation of effective A-weighted sound pressure levels when hearing protectors are worn

Acoustique — Protecteurs individuels contre le bruit —

Partie 2: Estimation des niveaux de pression acoustique pondérés A en cas d'utilisation de protecteurs individuels contre le bruit

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www. iso. org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www. iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www. iso. org/iso/foreword. html.

This document was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise.*

This second edition cancels and replaces the first edition (ISO 4869-2:1994) which has been technically revised. It also incorporates the corrected version ISO 4869-2:1994/Cor.1:2006.

The main technical changes are:

In the prior edition of the standard the *H*, *M*, *L*, and *SNR* values were computed from the group average data by frequency. In this edition, the values are computed subject by subject and then combined to provide both a mean value and a standard deviation value so that population distribution can be estimated. The sound attenuation values for the frequency 63 Hz have been excluded from the *H*, *M*, *L* and *SNR* calculation methods since this test frequency is optional in ISO 4869-1. Prior to rounding to the nearest integer, values derived using this edition deviate from those derived using the previous edition by less than 1 dB.

A list of all parts in the ISO 4869 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document estimates an "effective" level, i.e. the A-weighted sound pressure level at the head centre with the listener absent, minus the attenuation of the hearing protection devices. Effective values are estimated since those are required to assess noise hazard with respect to permissible noise exposure limits. An effective level differs from that in the ear canal since it has been converted to a sound-field value via the transfer function of the open ear. Effective levels are typically 5 dB to 10 dB less than ear canal levels depending on the spectrum of the incident noise.

Ideally, the A-weighted sound pressure level effective when a hearing protector is worn should be estimated on the basis of both the octave-band sound attenuation data of the hearing protector (measured in accordance with ISO 4869-1) and the octave-band sound pressure levels of the noise. It is recognized, however, that in many situations information on the octave-band sound pressure levels of the noise might not be available. Therefore, for many practical purposes, there is a need for simpler methods to determine the effective A-weighted sound pressure levels which are only based on the A- and C-weighted sound pressure levels of the noise. This document addresses both of these situations by specifying an octave-band calculation method as well as two alternative simplified procedures, the *HML* method and the *SNR* method.

The octave-band method is a calculation method involving the workplace octave-band sound pressure levels and the octave-band sound attenuation data for the hearing protector that is being assessed. Although it can be thought of as an "exact" reference method, it has its own inherent inaccuracies, since it is based upon mean sound attenuation values and standard deviations for a group of test subjects, and not the specific sound attenuation values for the individual person in question.

The *HML* method specifies three attenuation values, *H*, *M* and *L*, determined from the octave-band sound attenuation data of a hearing protector. These values, when combined with the C- and A-weighted sound pressure levels of the noise, are used to calculate the effective A-weighted sound pressure level when the hearing protector is worn.

The *SNR* method specifies a single attenuation value, the single number rating, determined from the octave-band sound attenuation data of a hearing protector. This value is subtracted from the C-weighted sound pressure level of the noise to calculate the effective A-weighted sound pressure level when the hearing protector is worn.

Due to the large spread of the sound attenuation provided by hearing protectors when worn by individual persons, all three methods are nearly equivalent in their accuracy in the majority of noise situations. Even the simplest method, the *SNR* method, will provide a reasonably accurate estimate of the effective A-weighted sound pressure level to aid in the selection and specification of hearing protectors. In special situations, for example especially high- or low-frequency noises, it is necessary to use either the *HML* or the octave-band method.

Depending on the choice of a certain parameter in the calculation process, various protection performances can be obtained. It should be noted that the protection performance values for all three methods are only valid when:

— the hearing protectors are worn correctly and in the same manner as they were worn by subjects when carrying out the ISO 4869-1 test;

— the hearing protectors are properly maintained;

— the anatomical characteristics of the subjects involved in the ISO 4869-1 test are a reasonable match for the population of actual wearers.

Thus, the principal source of potential inaccuracy in use of the three methods described in this document is the basic ISO 4869-1 input data. If the input data do not accurately describe the degree of protection achieved by the target population, then no calculation method will provide sufficient accuracy.

The uncertainty of the attenuation values and ratings is described in <u>Annex E</u>.

NOTE   Differences of 3 dB or less in the determination of the effective sound pressure level for comparable hearing protectors are generally insignificant.

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Acoustics — Hearing protectors —

Part 2:
Estimation of effective A-weighted sound pressure levels when hearing protectors are worn

1 Scope

This document specifies three methods (the octave-band, *HML* and *SNR* methods) of estimating the A-weighted sound pressure levels effective when hearing protectors are worn. The methods are applicable to either the sound pressure level or the equivalent continuous sound pressure level of the noise. Although primarily intended for steady noise exposures, the methods are also applicable to noises containing impulsive components. It is possible that these methods could not be suitable for use with peak sound pressure level measurements.

The octave-band, *H*, *M*, *L* or *SNR* values are suitable for establishing sound attenuation criteria for selecting or comparing hearing protectors, and/or setting minimum acceptable sound attenuation requirements.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 4869-1, *Acoustics — Hearing protectors — Part 1: Subjective method for the measurement of sound attenuation*

ISO 9612:2009, *Acoustics — Determination of occupational noise exposure — Engineering method*

IEC 61672-1, *Electroacoustics — Sound level meters — Part 1: Specifications*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 4869-1 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
protection performance
x
percentage of individuals for which the achieved protection is equal to or greater than the designated value, where the percentage is indicated by adding a subscript to the symbols representing the different methods, e.g. APV_{fx}, H_x, M_x, L_x, SNR_x

Note 1 to entry: The value of protection performance is often chosen to be 84 % [corresponding to the constant $\alpha = 1$ (see Clause 5)].

3.2
effective A-weighted sound pressure level
$L'_{p,Ax}$
A-weighted sound pressure level effective when a given hearing protector is worn for a specified protection performance, x, and a specific noise situation

Note 1 to entry: It is calculated in accordance with any of the three methods specified in ISO 4869-2.

3.3
predicted noise level reduction
PNR_x
difference between the A-weighted sound pressure level of the noise, $L_{p,A}$, and the effective A-weighted sound pressure level, $L'_{p,Ax}$ when a given hearing protector is worn for a specified protection performance, x, and a specific noise situation

3.4
assumed protection value
APV_{fx}
value representing the attenuation in that octave band for a particular octave band, f, a specified protection performance, x, and a given hearing protector

3.5
high-frequency attenuation value
H_x
value representing the predicted noise level reduction, PNR_x, for noises with $(L_{p,C} - L_{p,A}) = -2$ dB for a specified protection performance, x, and a given hearing protector

3.6
medium-frequency attenuation value
M_x
value representing the predicted noise level reduction, PNR_x, for noises with $(L_{p,C} - L_{p,A}) = +2$ dB for a specified protection performance, x, and a given hearing protector

3.7
low-frequency attenuation value
L_x
value representing the predicted noise level reduction, PNR_x, for noises with $(L_{p,C} - L_{p,A}) = +10$ dB for a specified protection performance, x, and a given hearing protector

3.8
single number rating
SNR_x
value that is subtracted from the measured C-weighted sound pressure level, $L_{p,C}$, in order to estimate the effective A-weighted sound pressure level, $L'_{p,Ax}$ for a specified protection performance, x, and a given hearing protector

4   Measurement of sound attenuation of hearing protectors

The one-third-octave-band attenuation values of the hearing protector to be used in the calculation methods specified in this part of ISO 4869 shall be measured in accordance with ISO 4869-1.

5   Calculation of the assumed protection value, APV_{fx}, of a hearing protector for a selected protection performance

The calculation begins with the selection of the desired protection performance, x, and the associated constant α (see Table 1). When $\alpha = 1$ and $x = 84$ %, the subscripts to the attenuation values may be omitted.

The assumed protection value, APV_{fx}, of the hearing protector is calculated for each octave band using the following formula:

$$APV_{fx} = m_f - \alpha\, s_f \tag{1}$$

where

subscript f	represents the centre frequency of the octave band;
subscript x	represents the selected protection performance;
m_f	is the mean sound attenuation determined in accordance with ISO 4869-1;
s_f	is the standard deviation determined in accordance with ISO 4869-1;
α	is the inverse of the standard normal cumulative distribution for a specific protection performance, having the values given in Table 1.

Table 1 — Values of α for various protection performances x

Protection performance x %	Value of α
50	0,00
75	0,67
80	0,84
84	1,00
90	1,28
95	1,64
98	2,00

An example of the calculation of the assumed protection values, APV_{fx}, is given in Annex A.

6 Octave-band method

This method requires octave-band sound pressure levels of the noise and assumed protection values, APV_{fx}. Since the method is noise specific, the calculation shall be made for each noise situation.

The A-weighted sound pressure level effective when the hearing protector is worn, $L'_{p,Ax}$, is calculated using the following formula:

$$L'_{p,Ax} = 10\lg \sum_{k=1}^{8} 10^{0,1\left(L_{p,f(k)} + A_{f(k)} - APV_{f(k)x}\right)} \text{dB} \tag{2}$$

where

subscripts $f(k)$	represent the octave-band mid-frequency; $f(1) = 63$ Hz; $f(2) = 125$ Hz; $f(3) = 250$ Hz; …; $f(8) = 8\,000$ Hz;
$L_{p,f(k)}$	is the sound pressure level of the noise in the octave band;
$A_{f(k)}$	is the frequency weighting A in accordance with IEC 61672-1 at the octave-band mid-frequencies (see Table B.1).

If 63 Hz octave-band data for either the noise or the hearing protector are not available, then the summation in Formula (2) begins at 125 Hz. For the subsequent *HML* and *SNR* methods the computations

always begin at 125 Hz regardless of the availability of the data at 63 Hz. The resulting $L'_{p,Ax}$ value shall be rounded to the nearest integer.

An example of the estimation of the effective A-weighted sound pressure level when a given hearing protector is worn in a specific noise situation is given in Annex B.

7 *HML* method

7.1 General

This method requires C- and A-weighted sound pressure levels of the noise and *H*, *M* and *L* values.

7.2 Calculation of *H*, *M* and *L* values

Calculation of the H_x, M_x and L_x values in dB is based on eight reference noise spectra with different $(L_{p,C} - L_{p,A})$ values (see Table 2) and the individual sound attenuation values, $a_{jf(k)}$, of the hearing protector. The values are independent of the actual noise situation to which they are applied, and are calculated using the following formulae, where H_m, M_m, and L_m, refer to the mean values of the indices, and H_s, M_s, and L_s refer to the standard deviations of those indices:

$$H_x = H_m - \alpha H_s \tag{3}$$

$$M_x = M_m - \alpha M_s \tag{4}$$

$$L_x = L_m - \alpha L_s \tag{5}$$

where

    subscript *x*   represents the selected protection performance;

    α is a constant specified in Table 1.

$$H_m = \frac{1}{N} \sum_{j=1}^{N} H_j \tag{6}$$

$$M_m = \frac{1}{N} \sum_{j=1}^{N} M_j \tag{7}$$

$$L_m = \frac{1}{N} \sum_{j=1}^{N} L_j \tag{8}$$

$$H_s = \sqrt{\frac{1}{N-1} \sum_{j=1}^{N} (H_j - H_m)^2} \tag{9}$$

$$M_s = \sqrt{\frac{1}{N-1} \sum_{j=1}^{N} (M_j - M_m)^2} \tag{10}$$

$$L_s = \sqrt{\frac{1}{N-1} \sum_{j=1}^{N} (L_j - L_m)^2} \tag{11}$$